Space Weather Technical Forecast

Issued on Wednesday, 19 July 2023 at 13:21 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

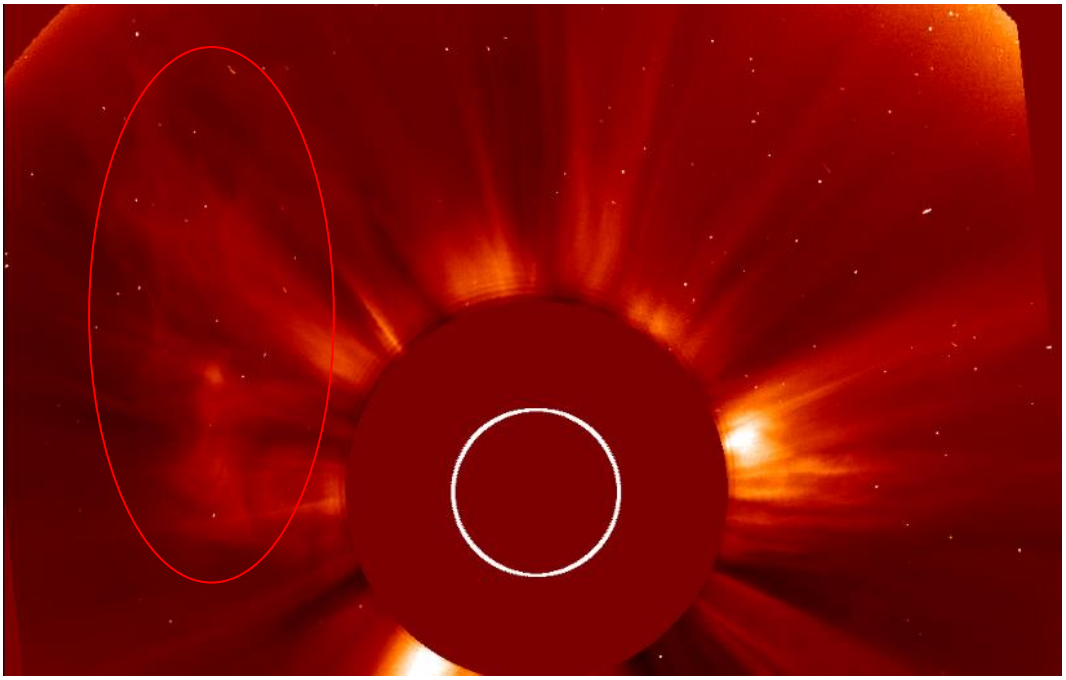
Space Weather Forecast Headline: Minor/Moderate R1/R2 Blackouts likely throughout. Chance of G1/G2 (Minor/Moderate Storms) Day 2 and Day 3.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity was Moderate, with several M-class flares observed. The largest one was a long duration and complex M2.1 flare peaking at 18/2027 UTC and attributed to two distinct regions, namely AR3363 and AR3376. There are currently up to eight sunspot regions on the visible disc, two of which are large, rather complex and near the central meridian. An active region has recently rotated onto the far side but has since been replaced by a new large region in the northeast quadrant.

Several CMEs were observed over the past 24 hours, most of which are not Earth-directed. However the CME that was observed leaving the Sun from the northeast limb around the same time as the M2.1 flare has been analysed. While the bulk of the ejecta is believed to head west of the Sun-Earth line, it may give a glancing blow on Day 3 (21st). Timing is still uncertain since a second analysis came back with a very different velocity.

Figure 0: Lasco C2 imagery showing the large CME that followed the M2.1 from AR3376



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Solar Wind / Geomagnetic Activity: The solar wind parameters are indicative of a gradual return to a slow regime. The solar wind slowly declined from 490 to 410km/s, with a below average density. The total magnetic field (IMF), Bt, has been weak and mostly below 6nT. The north-south component fluctuated between +5 and -2nT but was mostly orientated northward. Phi angle was consistently negative (towards the Sun). This resulted in a mostly Quiet geomagnetic activity. One Active (Kp4) interval was however observed between 18/1800-2100UTC, this most likely attributed to the disconnection with the magnetic cloud associated with the CME which arrived at Earth on 16 July.

Energetic Particles / Solar Radiation: The high energy (greater than 2MeV) electron flux remained largely at Moderate levels, with a peak of 936pfu observed at 18/1720 UTC. The 24-hour integrated fluence responded with a corresponding increase but remained well below the Active (1e8 integrated pfu) threshold. A fluence of 2.66e7 pfu was recorded at 19/0000 UTC. The high energy proton flux (greater than 10MeV), as observed by GOES16, is displaying a slight declining trend but remained above the Minor (S1) Storm threshold following the M5.7 flare that occurred on the 18/0000UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Activity is expected to be Moderate over the following days, with occasional M-class flares likely. AR3373 and AR3376 remain the most likely candidates, both currently in the northeast quadrant.

Solar Wind / Geomagnetic Activity: Two Earth-directed CMEs feature in this forecast, with a glancing blow expected on Day 2 (20th) and another one on Day 3 (21st). However confidence is very low with regards to the strength and timing of the second CME. Connections with coronal hole high speed streams may become established at times but these are small and most likely to be masked by CME effects. Solar winds should remain slightly elevated on Day 1 but become mostly elevated and perhaps strong at times on Days 2 and 3, before slowly easing on Day 4.

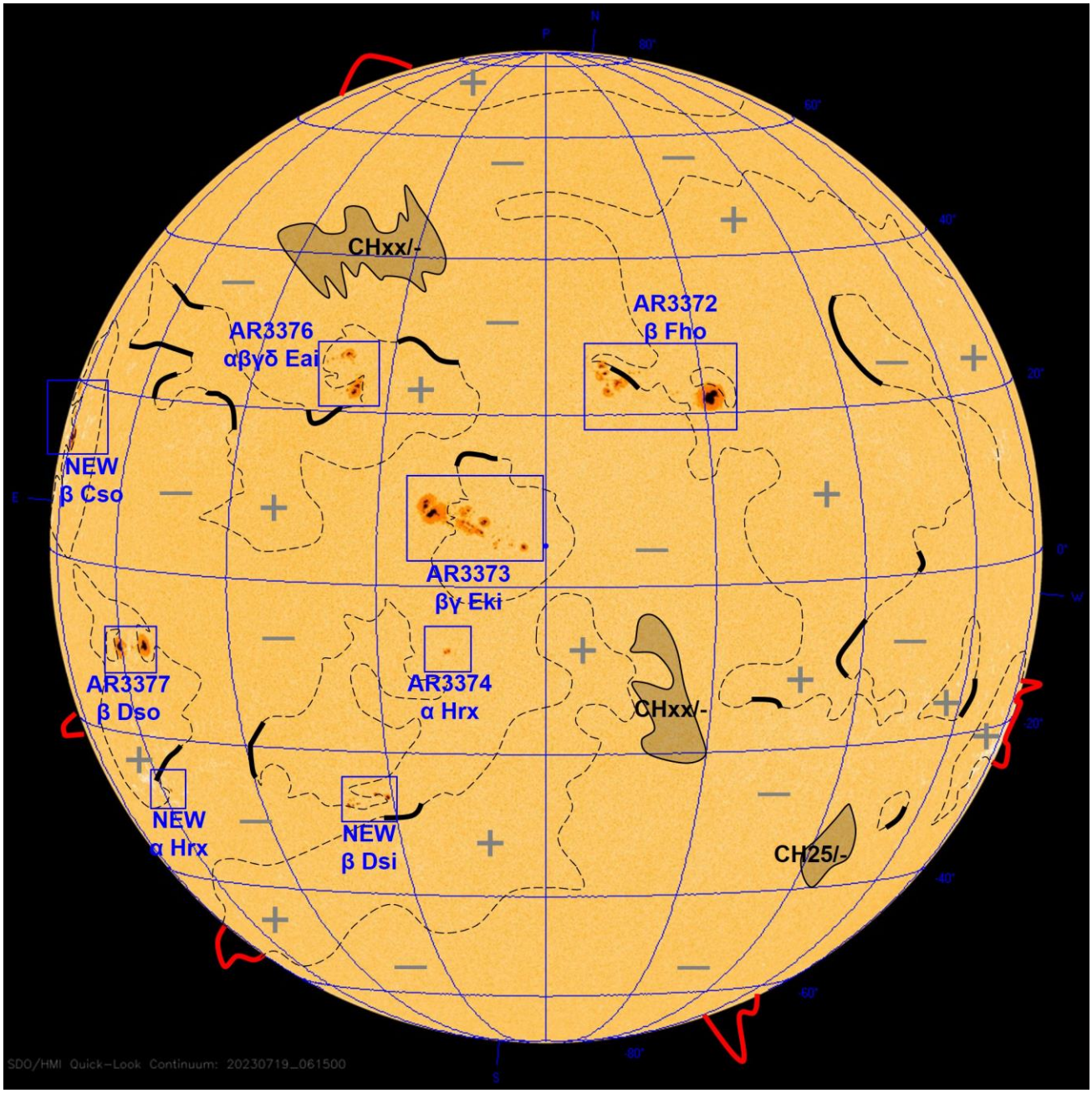
Geomagnetic activity is therefore expected to be Quiet to Unsettled on day 1 (19th). Activity then probably becoming Active with a chance of G1/G2 (Minor/Moderate) storms intervals on days 2 and 3 (20th & 21st). Activity returning to Quiet with a chance of Unsettled intervals by day 4 (22nd) as CME effects wane, but confidence is low as it will largely depends on the arrival time of the CME.

Energetic Particles / Solar Radiation: The high energy electron flux (greater than 2MeV) is expected to become High during the diurnal peak on Day 1, before more likely Low or Moderate on Days 2 and 3, under the influence of the two expected CMEs. High again on Day 4, perhaps leading the fluence to breach the Active threshold (1e8 integrated pfu). The current ongoing minor (S1) solar radiation storm will probably continue for much of the period, especially if further significant proton rich flares are emitted.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Figure 1. Solar Analysis Valid 19/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Geomagnetic Storms:

Two Earth-directed CMEs feature in this forecast. The first one originates from the M5.7 flare that occurred around 18/0000 UTC. While the bulk of the ejecta is expected to pass south of Earth, it may give a glancing blow during the UTC morning of the 20th (Day 2). The second one was observed leaving the Sun from the northeast limb around the same time as the M2.1 flare that occurred around 18/2000UTC. While the bulk of the ejecta is believed to head west of the Sun-Earth line, it may give a glancing blow on Day 3 (21st). However satellite imagery was very scarce during the eruption, giving low confidence in the analysis. A second analysis also came back with a faster speed, suggesting an earlier arrival.

Otherwise, Earth is currently under the waning influence of the CME that arrived late on 16 July, with slightly elevated solar winds. Connections with coronal hole high speed streams may become established at times but these are small and most likely to be masked by CME effects, with minor geomagnetic impacts.

Geomagnetic activity is therefore expected to be Quiet to Unsettled on day 1 (19th). Activity then probably becoming Active with a chance of G1/G2 (Minor/Moderate) storms intervals on days 2 and 3 (20th & 21st). Activity returning to Quiet with a chance of Unsettled intervals by day 4 (22nd) as CME effects wane, but confidence is low as it will largely depends on the arrival time of the CME.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	50	30	10
Strong	G3	No	1	10	10	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

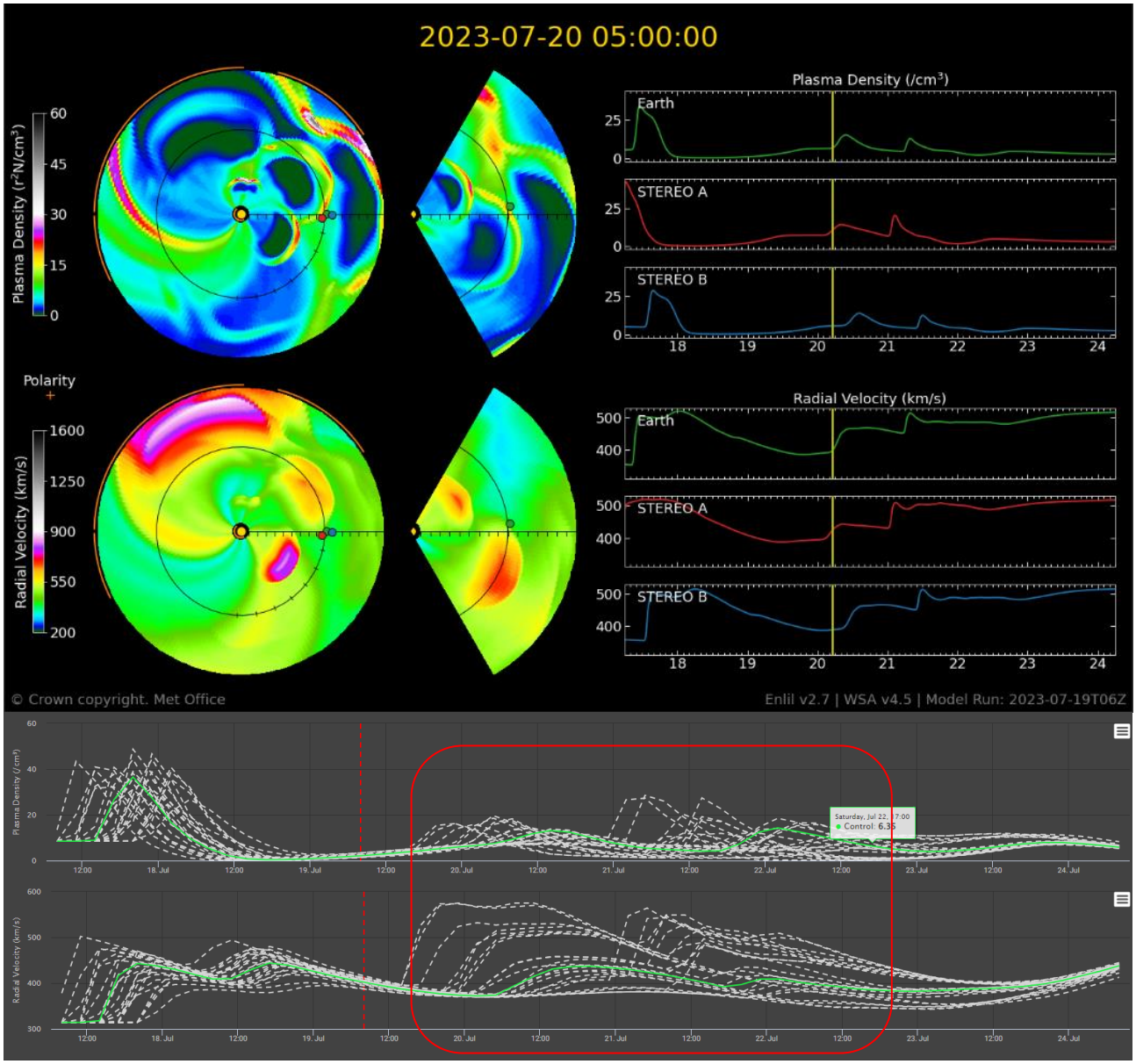
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
18/0145 UTC	Asymmetric full	M5.7 from AR3363	SW quadrant, near the horizon	1630 km/s	20/0600 UTC +/- 6hrs	Bulk of the ejecta passing south of Earth
18/2300 UTC	Asymmetric full	M2.1 from AR3376	NE quadrant	1200 km/s	21/0900 UTC +/- 6hrs	Bulk of the ejecta passing left of Sun-Earth line

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Figure 2: MOSWOC Enlil and ensemble, showing a possible CME arrival on the 20th & 21st



Radio Blackouts - X-Ray Flares:

Solar activity was Moderate, with several M-class flares observed. The largest one was a long duration and complex M2.1 flare peaking at 18/2027 UTC and attributed to two distinct regions, namely AR3363 and AR3376. An M1.4 was also observed at 19/1057UTC from AR3363, which has recently rotated onto the far side

There are currently up to eight sunspot regions on the visible disc. AR3363 probably remains complex and unstable but has now rotated onto the far side and is no longer visible. AR3372 remains a large open region, consisting of a large symmetric leader and a more complex broken trailer. It has however lost its delta and its magnetic structure has somewhat simplified in the last few hours. AR3373 is now the largest region. It remains large and complex but has lost several small spots and seems less active. AR3376 in the northeast has shown some simplification of the intermediate spots, however it remains quite active and north-south magnetically aligned. AR3377 near the southeast limb consists of two large spots and appears stable. The unnumbered region in the southeast quadrant has become more elongated, with multiple

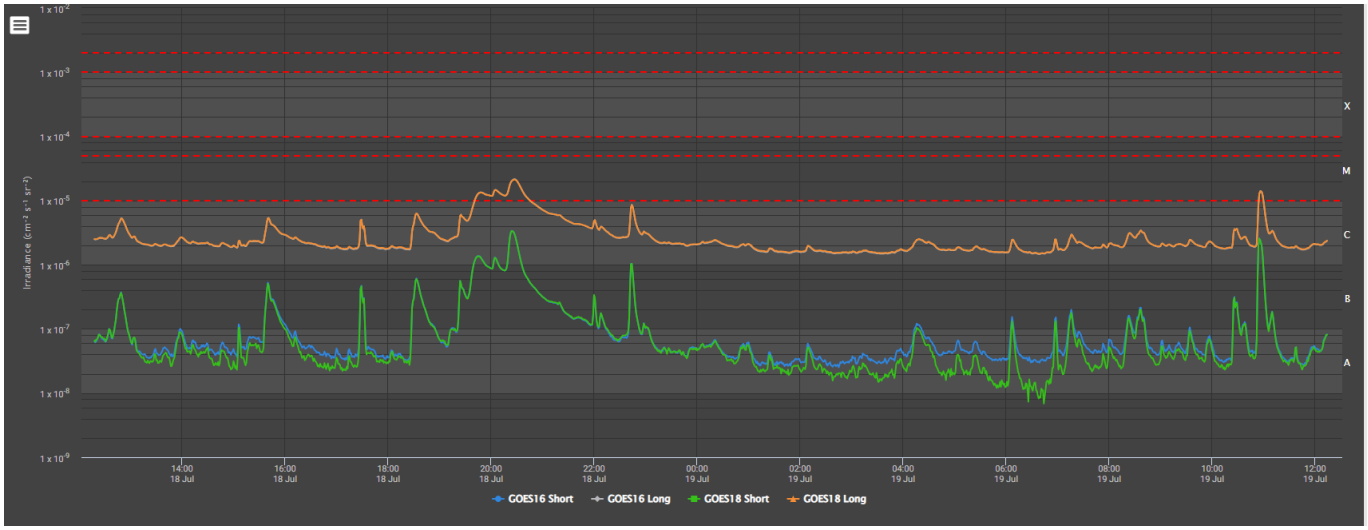
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

rudimentary penumbrae developing .A potentially very large large active region continues to emerge across the north-eastern limb. Remaining regions appear stable and relatively small. Activity is expected to be Moderate over the following days, with occasional M-class flares likely. The chance of an isolated X-class flare is slightly higher than raw probabilities following recent flaring events and displays a slight increasing trend since some of the largest and most active regions are expected to soon transfer onto the western hemisphere, namely AR3373 and AR3376 which are both in the northeast.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**R1-R2 M Class**	Yes	70	70	70	70
Very Active	**R3 to R5 X Class**	No	10	15	20	20

Figure 3: Latest X-ray flare activity, as observed by GOES-16



Solar Radiation Storms - (High Energy Protons):

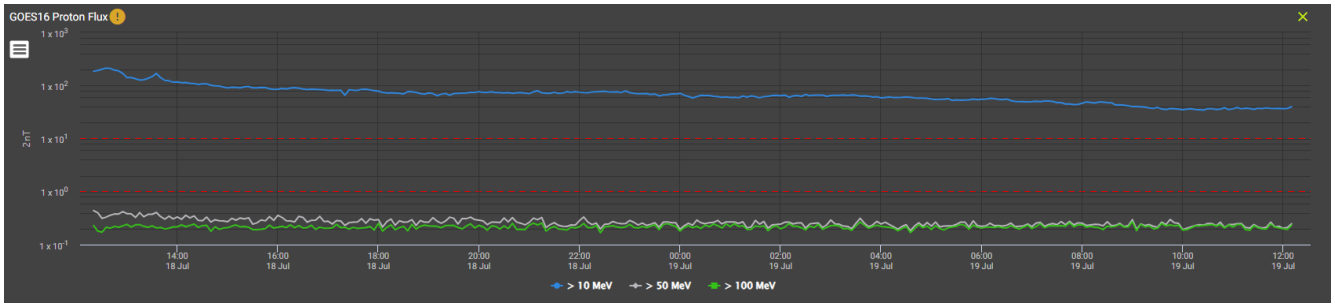
The high energy (greater than 10MeV) proton flux is currently above the minor storm (S1) threshold level. The region responsible for this storm, AR3362, has now rotated onto the far side and although it is no longer visible, it may still be able to produce solar storms and affect Earth, at least for another 24 hours. The risk will decline over the following days however, the current ongoing minor (S1) solar radiation storm will probably continue for much of the period. Further solar radiation storms may even aggravate the situation since some of the largest and most active regions are expected to soon transfer onto the western hemisphere, namely AR3373 and AR3376, both of which are currently in the northeast.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	80	70	60
Very Active	**≥ S3 ***	No	10	5	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Latest Proton Flux, as observed by GOES-16, showing a very slow decline towards the S1 threshold



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

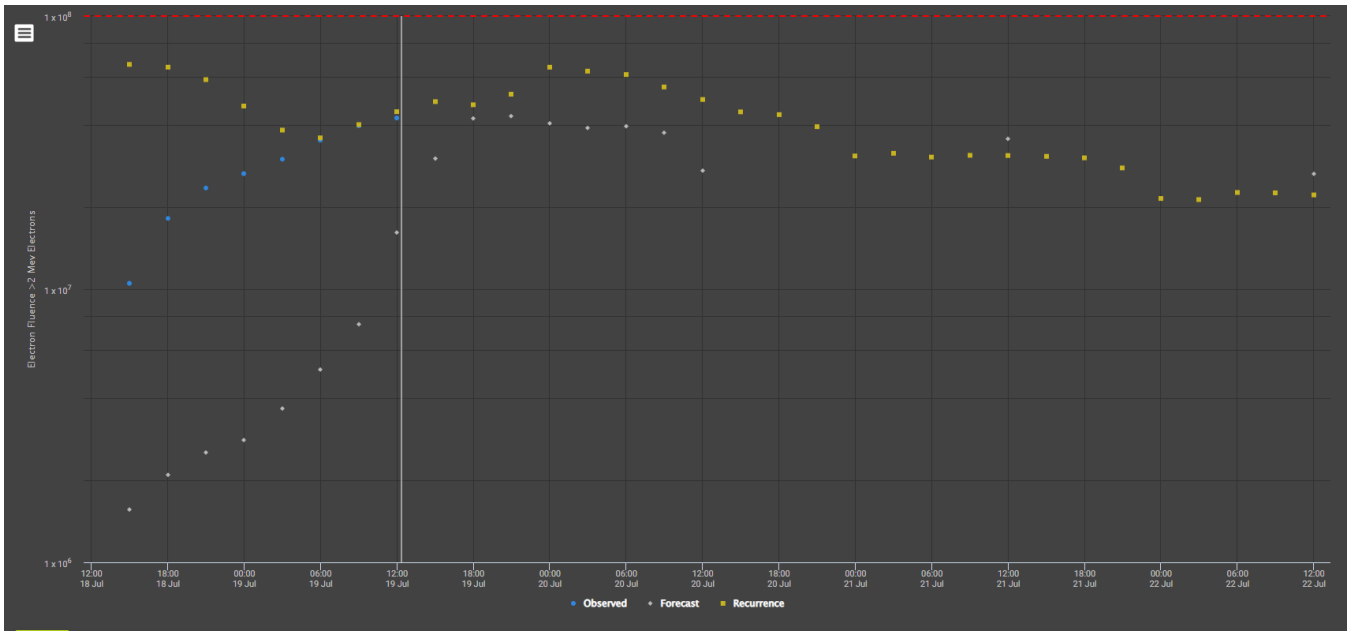
© Crown Copyright 2023. All Rights Reserved.

High Energy Electrons Event (≥ 2MeV):
High energy electron flux (greater than 2MeV) has been largely at Moderate levels in the past 24 hours following the CME that arrived on the 16th, the associated magnetic cloud progressively charging the radiation belts. A further rise is expected on day 1, the flux likely to become high for a time during the diurnal peak. The denser and stronger winds associated with the expected CMEs may reduce temporarily the electron flux but the electron flux should replenish the radiation belts by Day 4 (22nd), leading the fluence to potentially breach the Active threshold (1e8 integrated pfu).

Low confidence in the timing though. The latest REFM output is in reasonable agreement but it is thought to under-estimate the impacts of the coming CMEs.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	40	20	30	60
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	20

Figure 5: Latest REFM output



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2023. All Rights Reserved.